

ELECTRONIC FLIGHT DISPLAY DEVELOPMENT SUPPORTED BY COMMERCIAL-OFF-THE-SHELF TOOLS

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Abstract

At the Institute of Flight Mechanics and Flight Control of the Technische Universität München a development flight simulator has been established based on Commercial-Off-The-Shelf hardware and software elements to evolve new concepts for cockpit displays. The display design has been conducted in co-operation with the Department of Aircraft and Ships of the Technical University of Budapest.

The paper describes the simulator, the applied Commercial-Off-The-Shelf tools, the head up display and the touchscreen equipped head down displays. It is shown how the basic control and command functions work and how some special functions can be implemented making use of the further opportunities of the touchscreen.

1 Introduction

Modern aircraft provide a huge amount of detailed information about the condition of their systems, flight conditions, navigation situation etc., for the pilot. On the one hand these data enhance the situation awareness of the pilot, on the other hand presenting too much information can rise the mental effort of the pilot to an unacceptable high level. Therefore, a proper display design is necessary.

At the Institute of Flight Mechanics and Flight Control of the Technische Universität München a development flight simulator has been established for testing and evaluating new concepts for head up displays (HUD) and head down displays (HDD). In order to shorten the development time and concentrate on the display design itself Commercial-Off-The-Shelf (COTS) tools were used. These displays were developed in tight cooperation with the Department of Aircraft and Ships of the Technical University of Budapest.

2 Commercial-Off-The-Shelf Tools

To reduce development cost and time and to overcome the inflexibility of a specially programmed software on a specific hardware platform COTS hardware and software elements have been used for the establishment of the simulator. With this procedure not only the initial costs and efforts can be reduced, but maintenance and further improvements also will be faster and easier.

2.1 COTS Hardware

Unix workstations of Silicon Graphics Inc. have been chosen for the hardware basis of the simulator. These workstations are fully compatible at the execution code level, so the once developed software can run at different workstations without changes. This way the

software development can be separated from the hardware, so the evolution of the hardware can be easily followed by simply changing whole machines or some parts, e.g. the graphic boards to achieve higher performance.

2.2 COTS Software

Two COTS software tools have been used, both provided by Virtual Prototypes Inc. They are:

- Flight Simulation Program (FLSIM) is a reconfigurable flight simulator program, which can model the flight dynamics of aircraft with 6 degrees of freedom in real time with user selectable frame rates up to 120 Hz. FLSIM provides a graphical user interface to change all aircraft parameters including the coefficient curves to model aerodynamics or engines, and also provides a direct interface to VAPS,
- Virtual Applications Prototyping System (VAPS): this software package can be used to develop a graphical human-machine interface in a point-and-click fashion. As a result an ANSI C-code can be generated, which easily can be transported to various platforms. Since VAPS was chosen as the tool for the development of the avionics displays, it is described in more detail in the next subparagraph.

2.3 Design Process Using VAPS

The VAPS software package consists of five subsystems, as presented in Fig. 1. They are [1]:

1. The Object Editor is a point-and-click fashioned graphic editor with predefined input and output virtual object types, e.g. dial or knob. The design circle should be started using this editor. At the first step the graphical representation of the desired virtual instrument has to be drawn and then its behaviour has to be defined using the predefined object types. In the VAPS terminology this element is simply called “object”. More complex functionality can be achieved by hierarchically grouped objects. This

means, that each object can have some other object as part of it, e.g. a dial can have a light as its background. In one screen several objects can be defined, and then this structure is called “frame”.

2. The Integration Editor: each object has

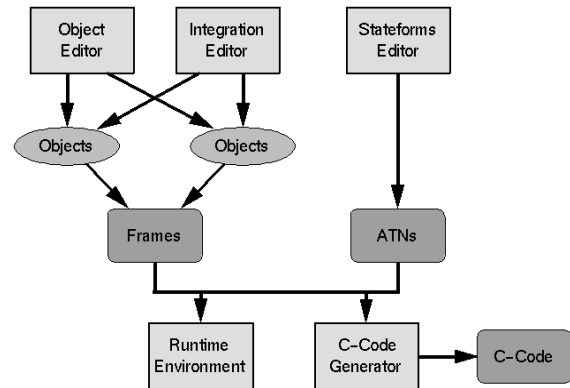


Fig. 1 VAPS design process

input or output plugs (or both) according to the definition made in the Object Editor. An object can send or receive information via these plugs. Of course the appropriate plugs should be connected to each other. These connections can be defined using the Integration Editor via “channels”. Each channel has one or more “members”, where one output plug (producer) and several input plugs (consumers) can be connected. Through the channels the objects can communicate to each other inside one application or with outer applications, which can also run on other computers, since the channels are also transferred via the network.

3. Stateforms Editor: some applications can work with fixed objects in fixed frames, but sometimes more complicated functionality is needed. While an application is running several “events” can occur, and the application has to react to them. This reactions can be described using the Stateforms Editor establishing the Augmented Transition Network (ATN) programme,

side-down. In normal configuration these monitors are displaying the Multi-Function Display (MFD), the Primary Flight Display (PFD) and the Navigation Display (ND) as presented in Fig. 2.

A 10" cathode ray tube is also mounted in the cockpit in the right hand console for purposes of the Flight Management System. This display is also equipped with a touchscreen, and driven by a PC. The PC is connected to the simulation host directly via RS232 interface, and handles also the glareshield panel.

The Digital Control Loading System is used for generating the control forces at the control column.

As the simulation host an SGI workstation is running FLSIM with different aircraft models.

A 150° by 40° wide Out-of-The-Window (OTW) scene is provided, which is presented by the 3-channel projection system. The projected scene is a 3-dimensional, textured synthetic scenery, generated by a SGI Onyx Reality Engine with Infinite Reality Graphics boards

4 Flight Displays

4.1 Head Up Display

The HUD is designed for high speed aircraft and is presented over the OTW scene, which is now a dark sky, because of the high service altitude of these aircraft. An example of the OTW scene together with the HUD is depicted in Fig. 3.

The HUD consists of two main parts:

- instruments providing numerical information according to the current position and speed of the aircraft,
- Perspective Flight Path Presentation providing 3-dimensional guidance information.

The scheme of the instruments follows the traditional arrangement: the speed indication is placed in the left side, the altitude indicator together with the vertical speed pointer are positioned in the right side and the heading information is presented in the middle of the display area, but at the top of it. The symbology corresponds to that of a modern HUD.

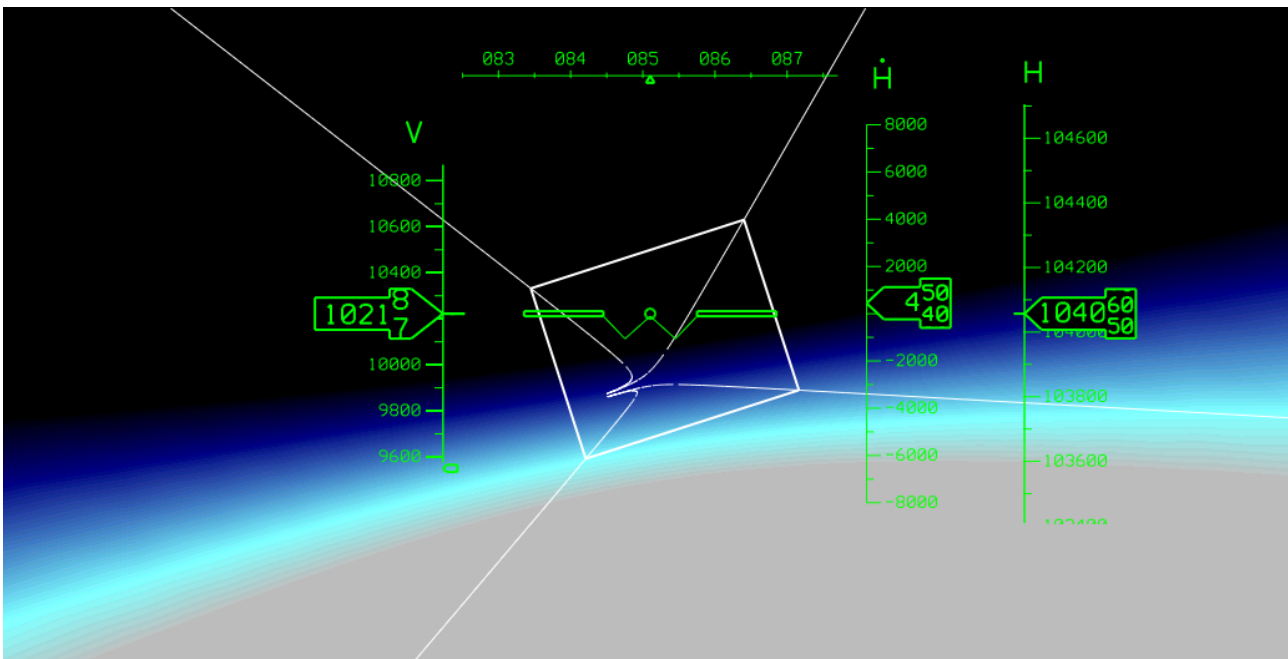


Fig. 3 Example of the HUD with 3-dimensional guidance information

The flight path is presented in the form of a tunnel. It is considered to allow an intuitive understanding of the future trajectory which the pilot has to follow. The tunnel image is incorporated in the display with the Guest Drawing Interpreter tool described in a subsequent section.

The attitude direction information is indicated by the horizon line of the OTW scene. Since the flight path has fixed position in space it pitches and rolls together the OTW scene.

4.2 Head Down Displays

The structure and the instruments of the HDDs are developed based on cockpit displays of modern airplanes, and are touchscreen features are added to these displays. In the following subchapters the primal elements of the displays are described. The touchscreen functions are presented in chapter 6.

Primary Flight Display

The layout of the Primary Flight Display follows the traditional T type arrangement [2].



Fig. 4 Example of the Primary Flight Display

In the middle the large attitude direction indicator is located. In the right side the altitude indicator and in the left side the speed indicator is positioned. The horizontal situation indicator is located in the lower middle part of the screen. Digital readouts are added to the speed and altitude indication tapes. The horizontal situation indicator consists of a compass rose, which is equipped with a digital readout and three needles, which can present VOR and ADF information. Beside these four main instruments a pointer type vertical speed indicator is placed in the lower right corner, and at the top the autopilot and autothrottle indicators are located. This layout is presented in Fig. 4.

Multi-Function Display

The Multi-Function Display consists of three major elements. In the left side the engine parameters are displayed for a two-engine aircraft. Dial gauges are used for presenting the main parameters with a clockwise rotating direction. For the fast readability all the nominal values are set to the “9 hour” position, where the pointer moves to the upper direction with increasing values. The warning lights are also integrated into these instruments. The whole background of the instrument becomes yellow and red, if critical values are registered. The upper right part is reserved for the system warning messages, in the lower right part the status of the flight controls and the gears are presented.

Navigation Display

In the main area of the Navigation Display the moving map is presented. The map follows the movement of the airplane in the way, that the current geographical position of the aircraft is matching the aircraft-reference in the display. The Navigation Display has two modes, one is the ARC mode (heading up) and the other is the MAP mode (north up). A virtual button is provided at the lower part of the display to toggle between the two modes. If the ARC mode is selected the map also turns maintaining heading up. The map consist of all NAVAIDs and airports and the flight path, if it is provided. Below the map the vertical profile of the flight

path is provided. An example of the Navigation Display is presented in Fig. 5.

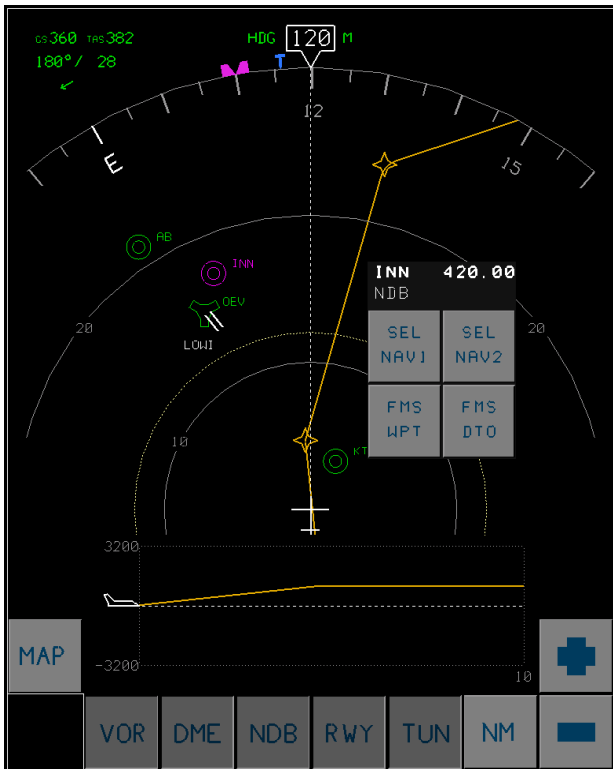


Fig. 5 Example of the Navigation Display

5 3D Object Presentation

Since VAPS is capable of 2-dimensional objects only there are no direct possibilities to define 3-dimensional objects, like a perspective flight path. For presenting such objects, VAPS offers the Guest Drawing Interpreter (GDI). The GDI was used to incorporate 3-dimensional guidance information in the cockpit displays.

5.1 GDI Object Handling

The GDI object allows the user to define his or her own graphics, map it into the VAPS object structure and handle it like a usual VAPS object. In runtime the VAPS calls the GDI object at the appropriate moment to refresh its data structures and to draw its graphics representation. As a result the user defined graphics appear among the VAPS graphics according to the current

state of the application. The GDI object shows a high flexibility.

5.2 Specific Code Integration with the GDI object

The structure of the software elements producing the OTW scene equipped by the HUD for high speed aircraft is depicted in Fig. 6.

The 2-dimensional HUD elements are built up from standard VAPS objects using all the possible complexity, i.e. hierarchy, grouping etc., and the behaviour is defined by an ATN. In Fig. 5 the box labeled VAPS represents these objects. Beside the 2-dimensional HUD elements this VAPS application also consists of the main routines for the whole HUD and for the OTW scene, so it is the central element of the HUD. This main system receives the inputs from the flight dynamics simulation and distributes them to the instrument objects. The aforementioned GDI object is also part of this VAPS block, and receives its inputs together with the other objects. After handling the data all objects are called to draw the appropriate graphics, so the presented OTW scene and the HUD is now refreshed according to the current simulation inputs.

The class definition of the perspective flight path presentation (PFPP in Fig. 6) is written in C++ programming language using OpenGL and is connected to the VAPS object structure via the GDI object

For configuring the perspective flight path presentation a separate VAPS Graphical User

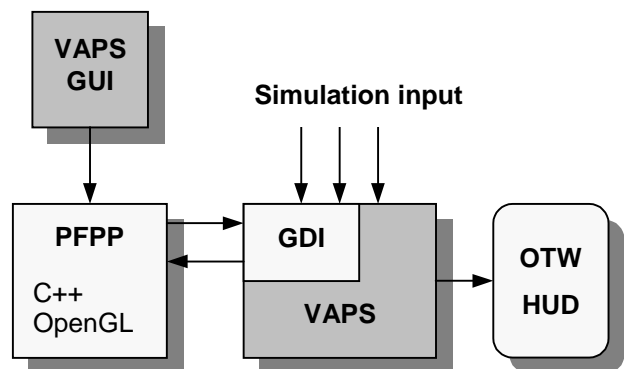


Fig. 6 Integrating the PFPP into the VAPS

Interface is also developed. This VAPS application runs detached from the main VAPS application, and there are no direct communication between them. The simulator operator can set the properties of the perspective flight path presentation (e.g. size, colors, trajectory, form, etc.) by it in runtime.

6 Use of Touchscreen

The Electronic Flight Information System (EFIS) is widely used in aircraft since years. As the number of functions of the displays grows the controls for invoking these functions become increasingly complex. For generating these controls, either multi-functional keys around the displays or control boards are installed. Using these controls the pilot action for launching a command happens at different locations of the cockpit than the system reaction occurs, resulting in spatial displacement. This effect requires higher attention of the pilot, thus rising the workload and decreasing the situational awareness. A touchscreen could be a useful device for improvement.

The advantage of a touchscreen is that by using it a graphical user interface can be established over the displays, where the pilot can directly manipulate them. The pilot actions and the system reactions occur at the same place and at the same time, so an immediate feedback is provided for the pilot. Thus, a natural operation and response possibility is provided for the pilot [3].

Two types of the touchscreen functionality were designed, the customisation and the parameter change. They are described in the next subparagraphs.

6.1 Customisation

The density of the data displayed or presented to the pilot is an important factor of workload. Only the data essential to the pilot's current needs should be displayed [4].

By the customisation feature several packages of information are provided. The pilot can select and activate the most appropriate package to the current flight situation by touch a virtual button in the screen. This feature works

inside one display, as its information flow is depicted in Fig. 7.

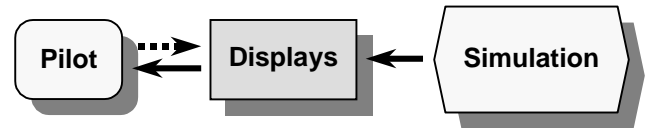


Fig. 7 Information flow at Customisation

An example of this functionality is presented in Fig. 8, which shows the change of units at the PFD. The touch sensitive area is placed on top of the altitude tape, where the current setting is presented. Pushing this button the pilot can toggle all the units of the display.

Other similar functions are:



Fig. 8 Example of Customisation

- A touch sensitive area is defined above the Speed Tape to toggle the indication between indicated airspeed and Mach number.
- At the left side of the Horizontal Situation Indicator in the PFD three touch-fields are defined to control its three needles. Pushing these buttons a NAVAID can be engaged to each pointers from the two sets of the preselected NAV sources. The alphanumeric information of the selected NAVAID is presented just in the touch-area, and the pointer shows its current direction (Fig. 4).
- In the lower part of the ND a row of virtual buttons are established. By these

buttons the moving map can be controlled. Several buttons are provided for decluttering the map and set the magnification and the units for it (Fig. 5).

6.2 Parameter Change

At the ND not only the virtual buttons are touch sensitive, but also the icons of the moving map. A special function, called parameter change, can be achieved through these icons. The information flow of an example of parameter change is presented in Fig. 9.

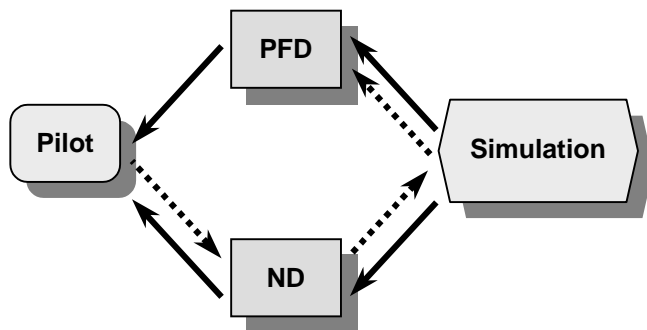


Fig. 9 Information flow at Parameter Change

Using the presented information of a display (e.g. the ND) the available bunches of information of another display (e.g. the PFD) or another system (e.g. the Flight Management System), which are defined in the simulation, can be changed.

In the current example of a NAVAID icon selection in the ND a small pop-up window appears giving detailed information about it and providing additional possibilities (Fig. 5). These options are to switch the selected NAVAID to the first or second set of the preselected NAV sources or send it to the flight management system to insert it in the flight path or to fly directly to it. Selecting one of these features some parameters will be changed in the simulation, which then affect other applications. For example, if a NAVAID is set to the NAV sources it can be used at the Horizontal Situation Indicator to engage it to one of the three needles, as it is described above.

7 Conclusions

Using Commercial-Off-The-Shelf tools the development time for the avionics displays of a flight simulator can be reduced.

The Guest Drawing Interpreter object is a useful tool for integrating not supported behaviour, such as a perspective flight path presentation.

Touchscreen features were considered to support the pilot.

8 References

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